N83 11197

CRYOGENIC FLUID TRANSFER - ORBITAL TRANSFER VEHICLE

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HUNTSVILLE, ALABAMA

EP6598

ORGANIZATION: STRUCTURES & PROPULSION LABORATORY EP43	MARSHALL SPACE FLIGHT CENTER	NAME: LEON J. HASTINGS
CHART NO.:	CRYOGENIC FLUID TRANSFER ORBITAL TRANSFER VEHICLE	DATE: JUNE 1982

PRESENTATION OUTLINE

√ REQUIREMENT OVERVIEW

- OTV CONFIGURATIONS
  - SIZE RANGE
  - INTERNAL HARDWARE
- GENERAL REFUELING CONCEPT

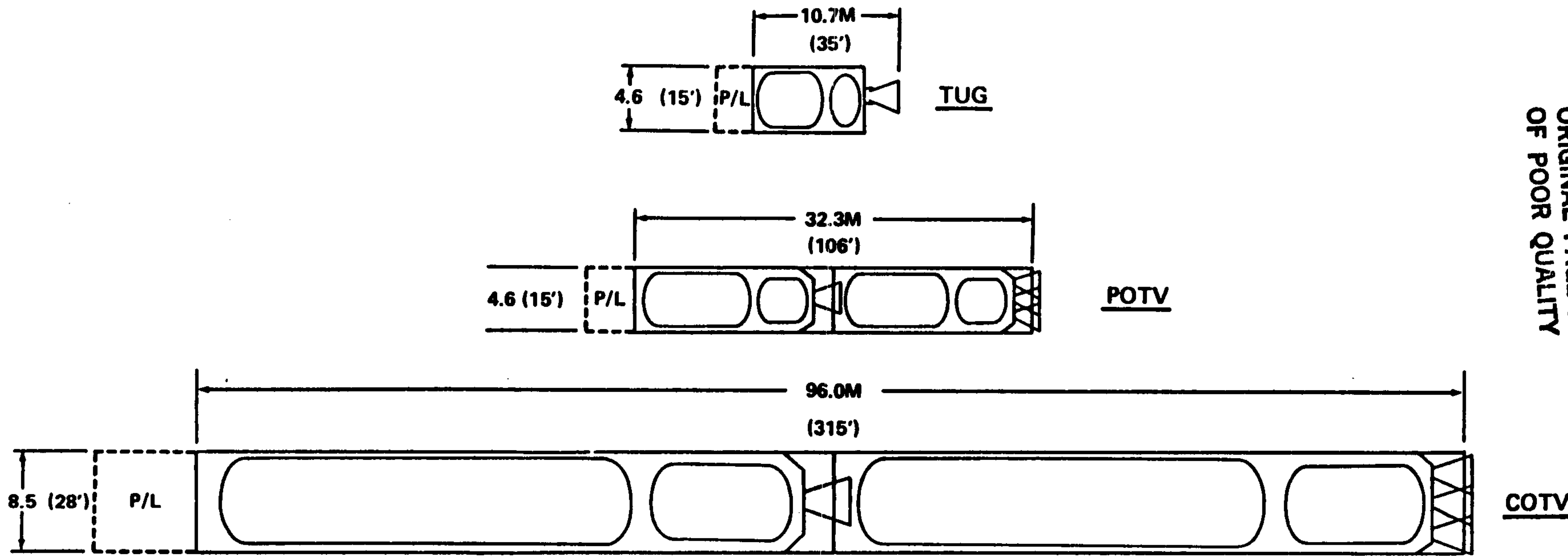
DESIGN/TECHNOLOGY CONSIDERATIONS

- TANK CHILLDOWN
  - INITIAL TANK CONDITIONS
  - CHILLDOWN THERMODYNAMICS
- TANK FILL
  - FILL THERMODYNAMICS
  - SUPPLY TANK EFFECTS
- SPECIAL ISSUES
  - RESIDUALS
  - START BASKET OR TANK PRESENCE

CONCLUSIONS

EP6558

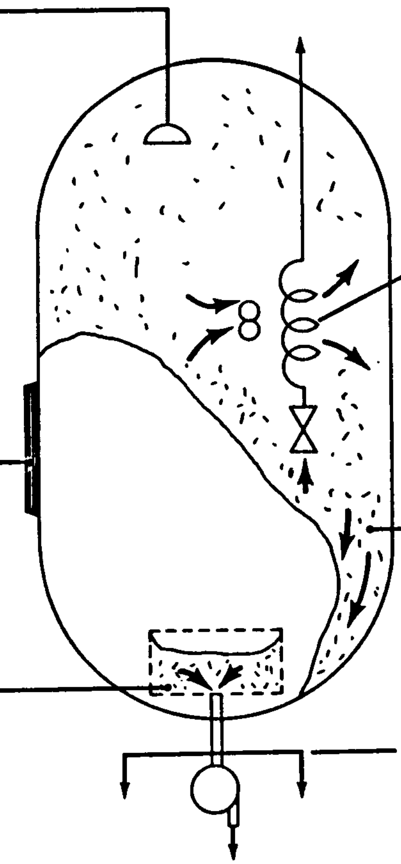
OTV CONFIGURATION OVERVIEW



VEHICLE	PROPELLANT	TANK VOLUME M^3 (FT^3)	PROPELLANT LOAD KG (LB)	OPERATING PRESS kN/M^2 (PSI)	MISSION
POTV	LO_2	41 (1450)	44,550 (99,000)	172 (25)	4 MEN FROM LEO TO GEO AND RETURN OR 100K TO GEO AND 60K RETURN WITH GEO REFUELING
	LH_2	116 (4100)	7,875 (17,500)	172 (25)	
COTV	LO_2	183 (6460)	197,400 (438,600)	172 (25)	500K FROM LEO TO GEO
	LH_2	549 (19,400)	37,260 (82,800)	172 (25)	

EP4401

OTV CRYOGEN MANAGEMENT CONSIDERATIONS



EP6559

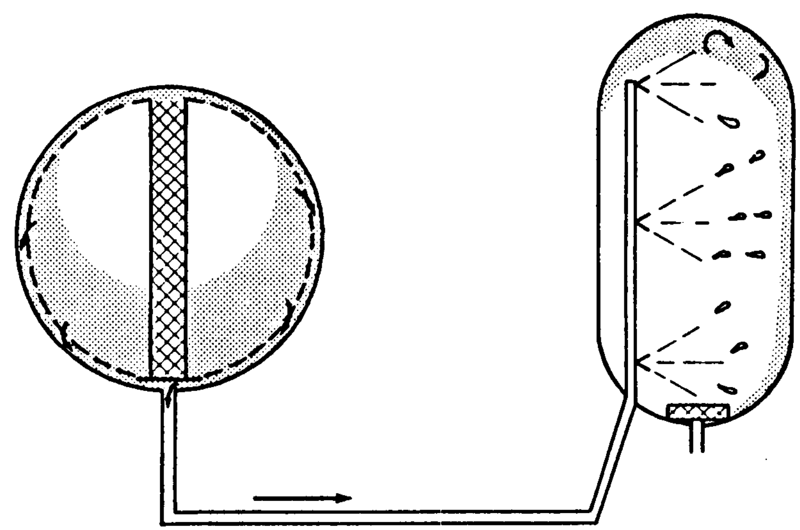
ORBITAL CRYOGEN TRANSFER CONSIDERATIONS

SUPPLY TANK

- STORAGE/VENTING
- ACQUISITION/EXPULSION
  - LIQUID ORIENTATION
  - BOILING/SCREEN DRYING
  - PRESSURIZATION
  - OUTFLOW RATE
  - RESIDUALS

RECEIVER (OTV)

- PRECHILL
  - INLET FLOWRATE/DISTRIBUTION
  - WALL CHILLDOWN
- NO VENT FILL
  - NON–EQUILIBRIUM THERMODYNAMICS
  - HELIUM PRESENCE
- START BASKET REFILL
- MASS GAUGING



TRANSFER LINE

- CHILLDOWN – PRESSURE SURGES
- FLUID LOADS
  - TRANSIENT
  - STEADY–STATE

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EP6599

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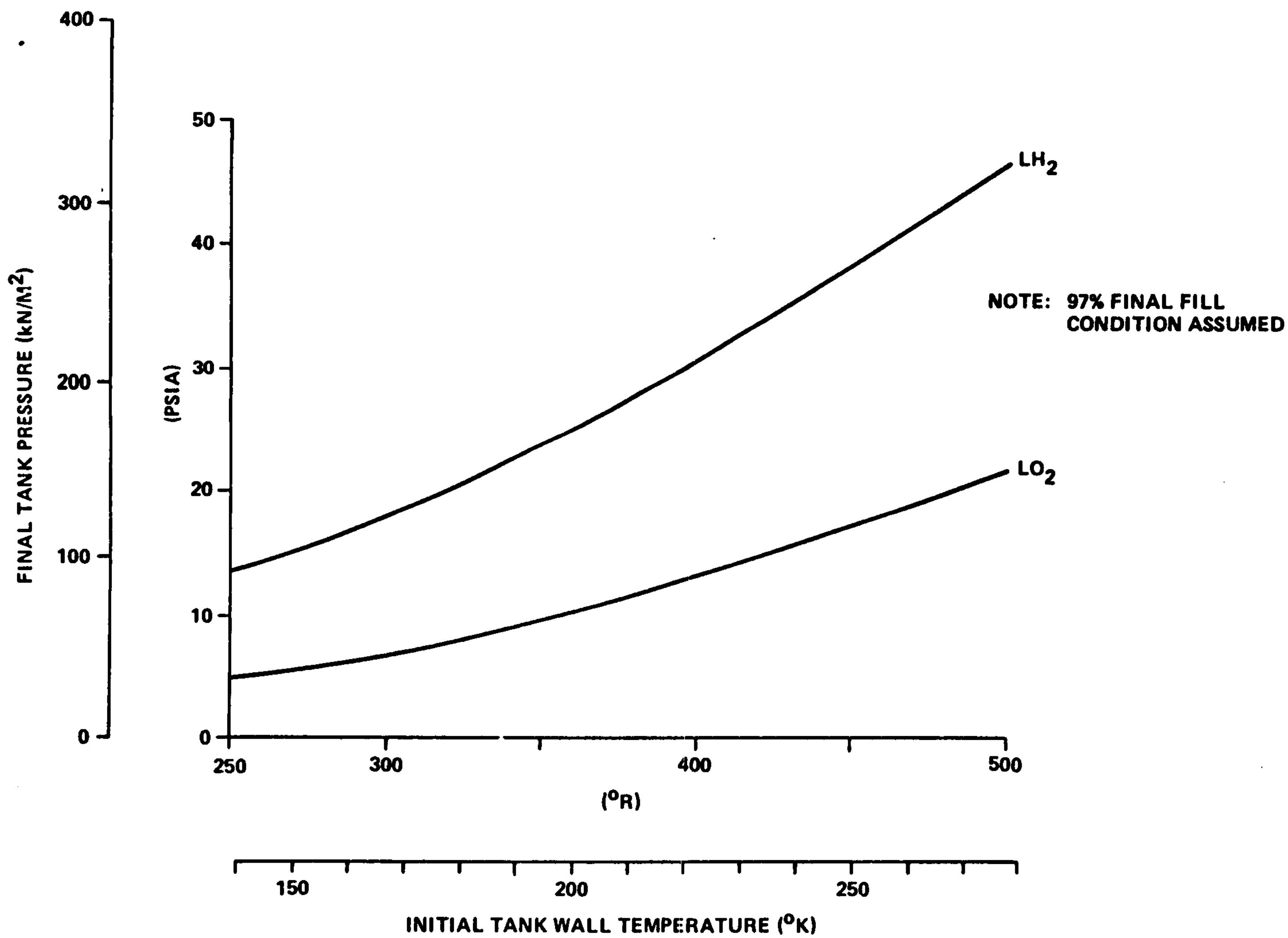
CONCLUSIONS

EP6563

INITIAL WALL TEMPERATURE EFFECTS ON POTV LH_2 TANK PRESSURES AFTER FILL



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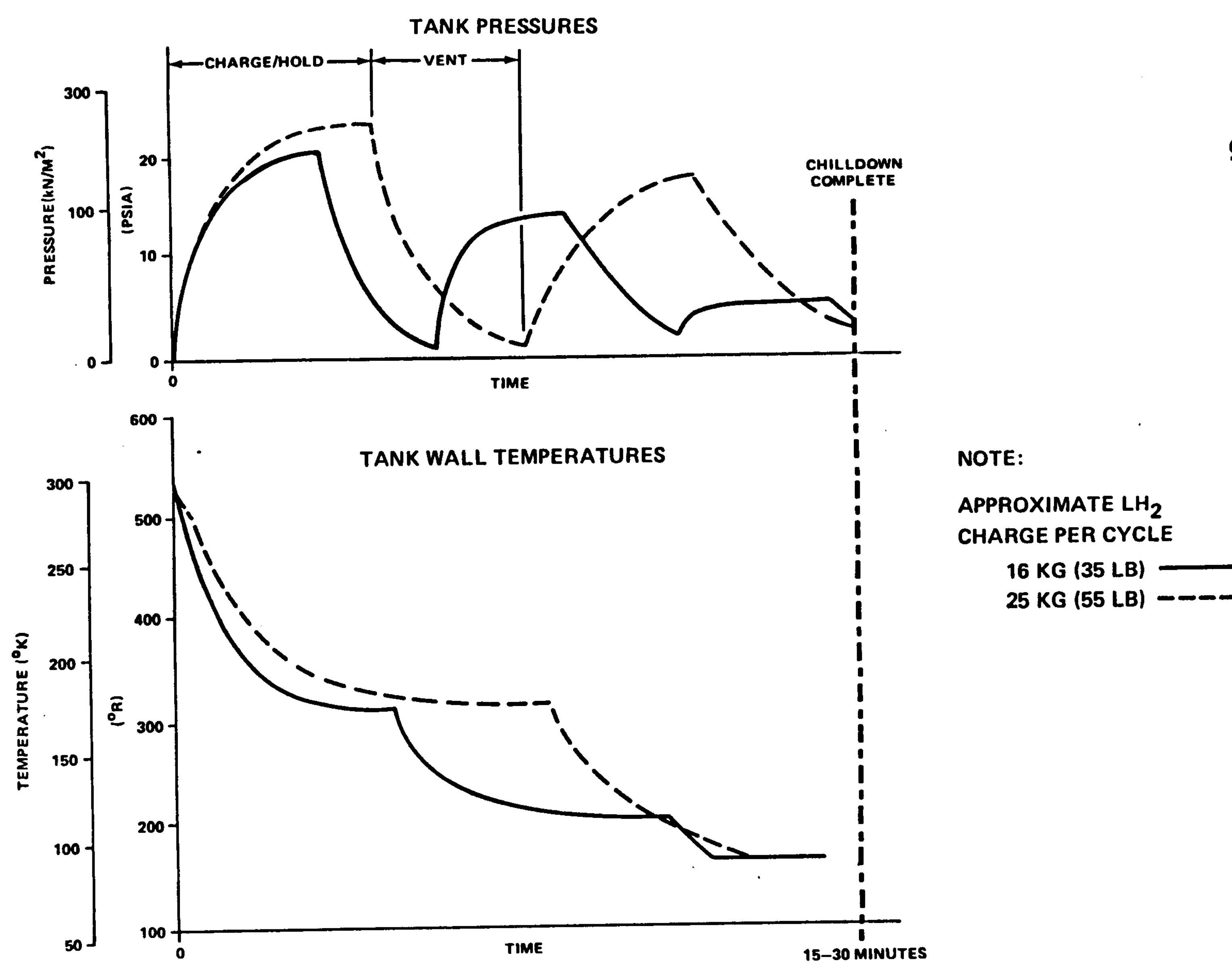
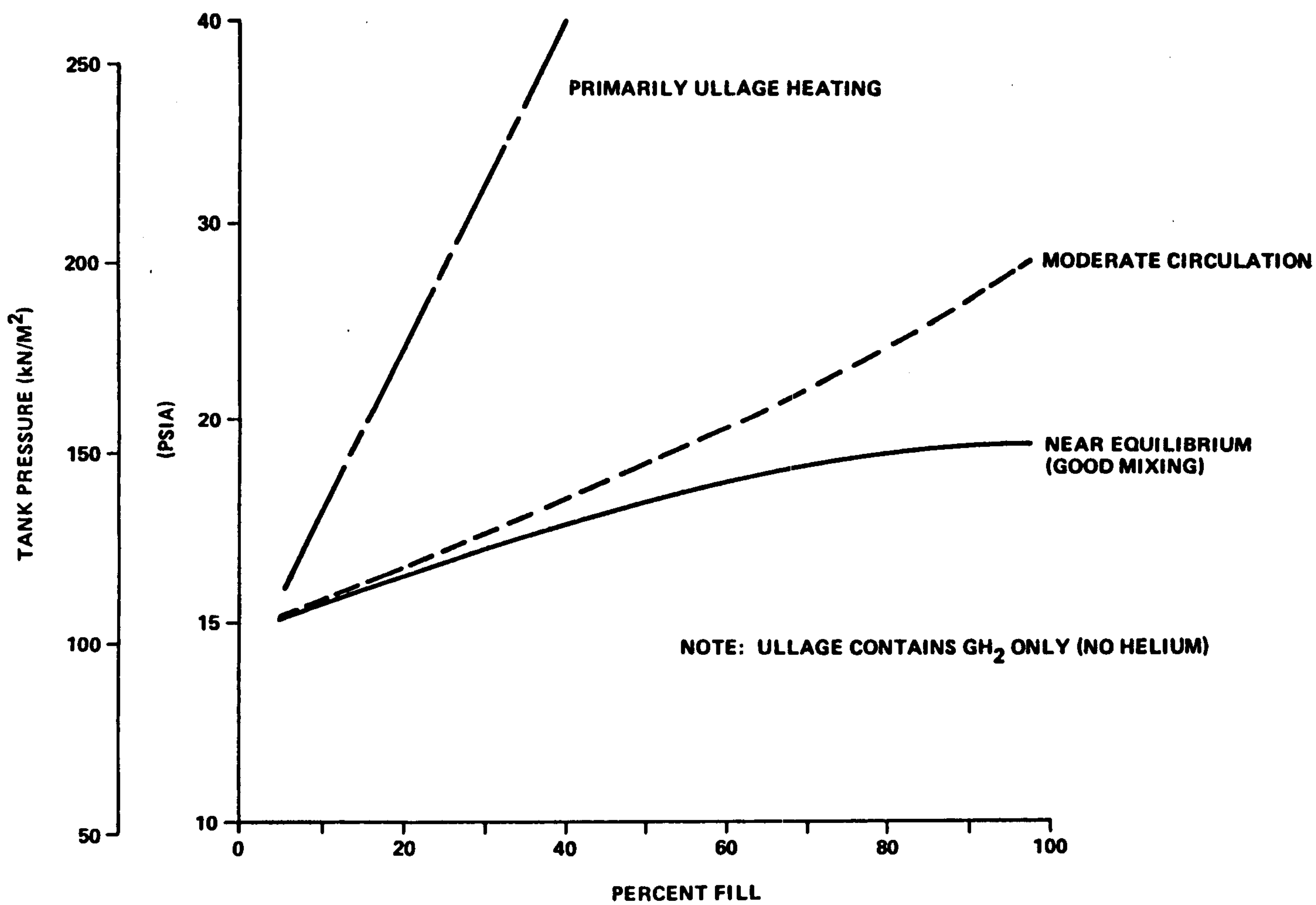
EP6560

POTV LH_2 TANK THERMODYNAMICS DURING CHILLDOWN



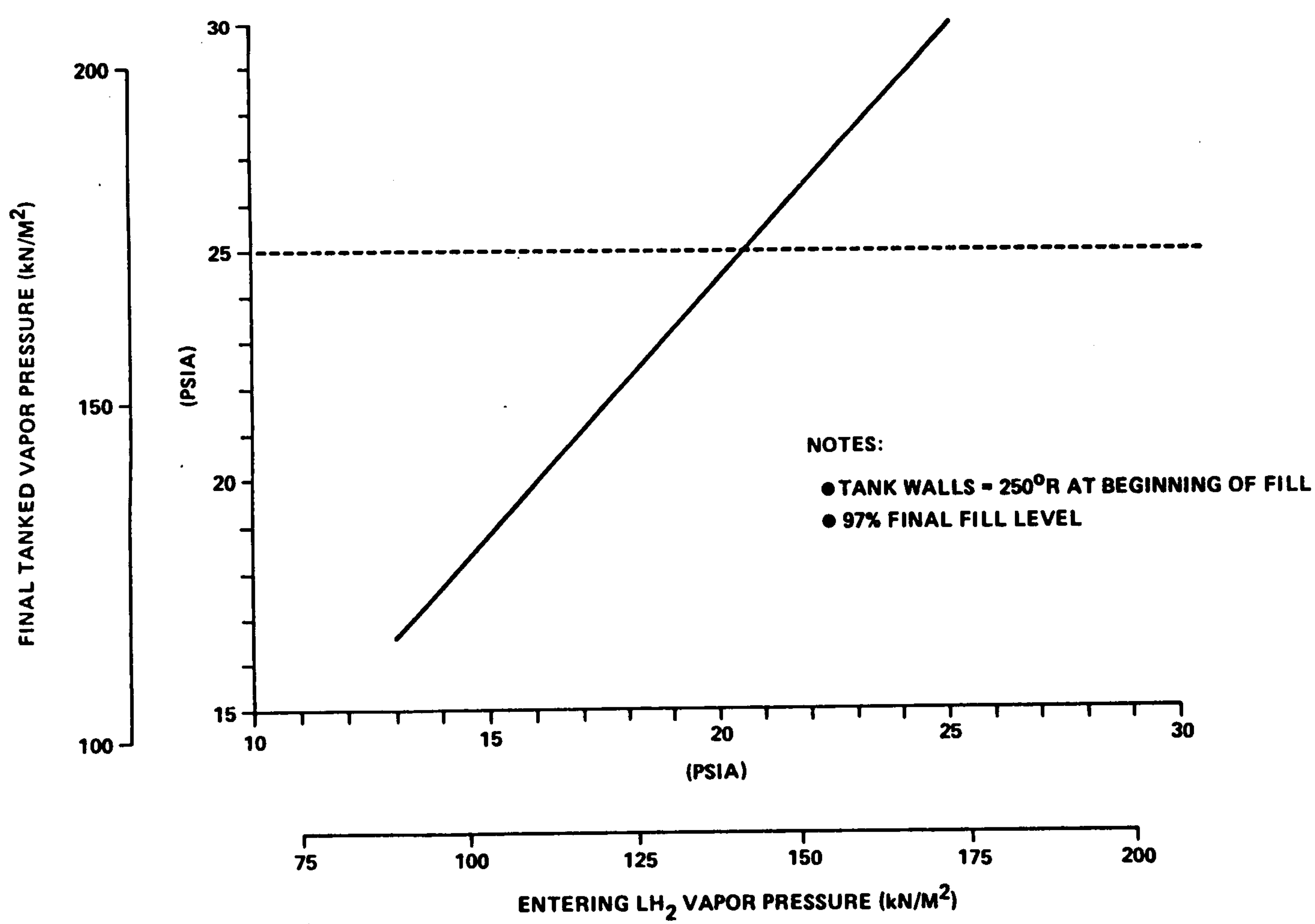
EP6562

POTV LH_2 TANK PRESSURES DURING ORBITAL FILL



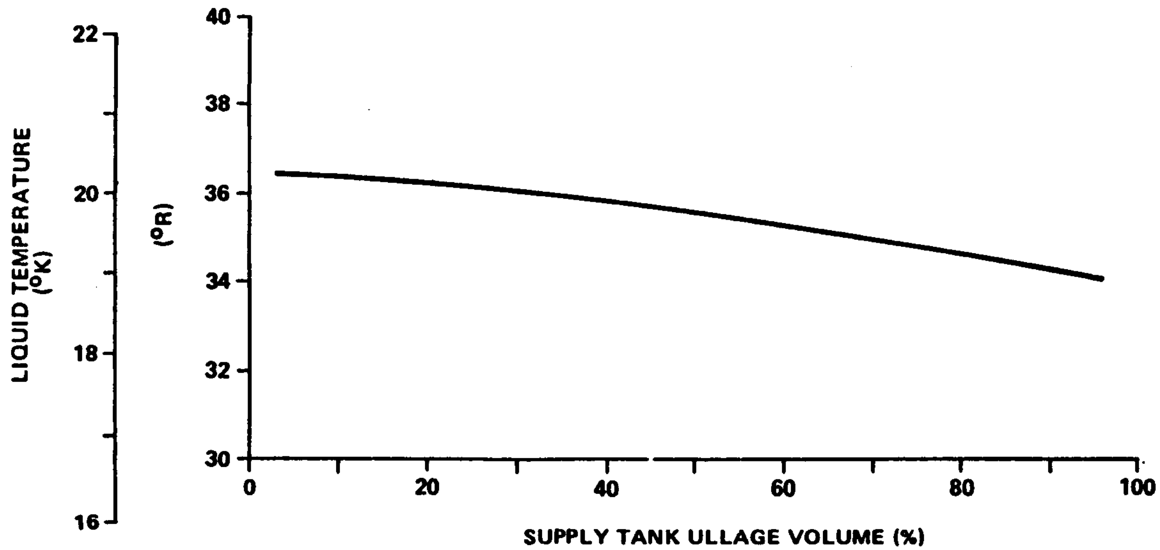
EP6564

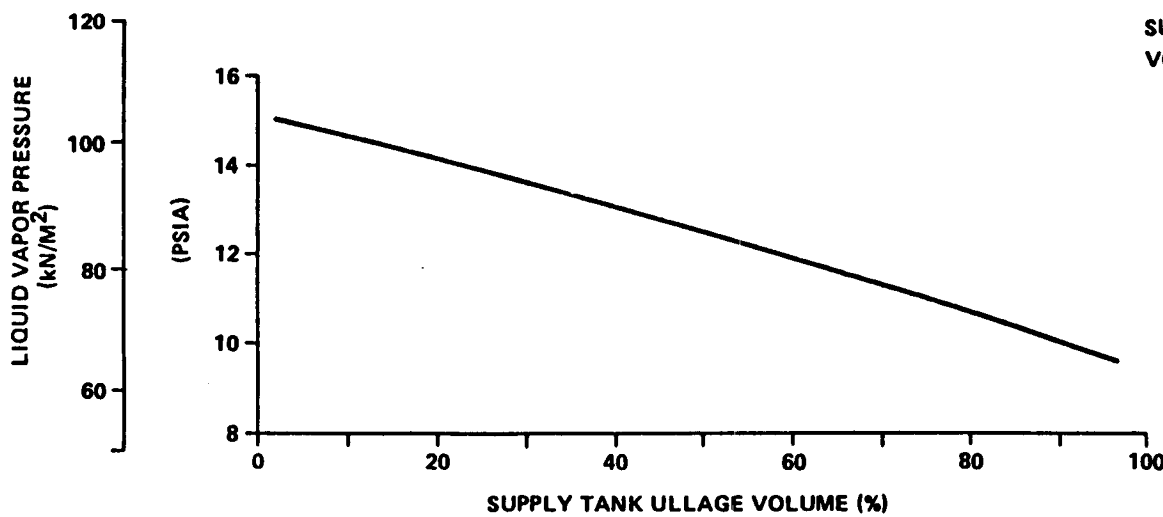
ENTERING LH_2 VAPOR PRESSURE EFFECTS ON POTV TANK PRESSURE AT FILL COMPLETION



EP6561

LH_2 SUPPLY TANK THERMODYNAMIC CONDITIONS



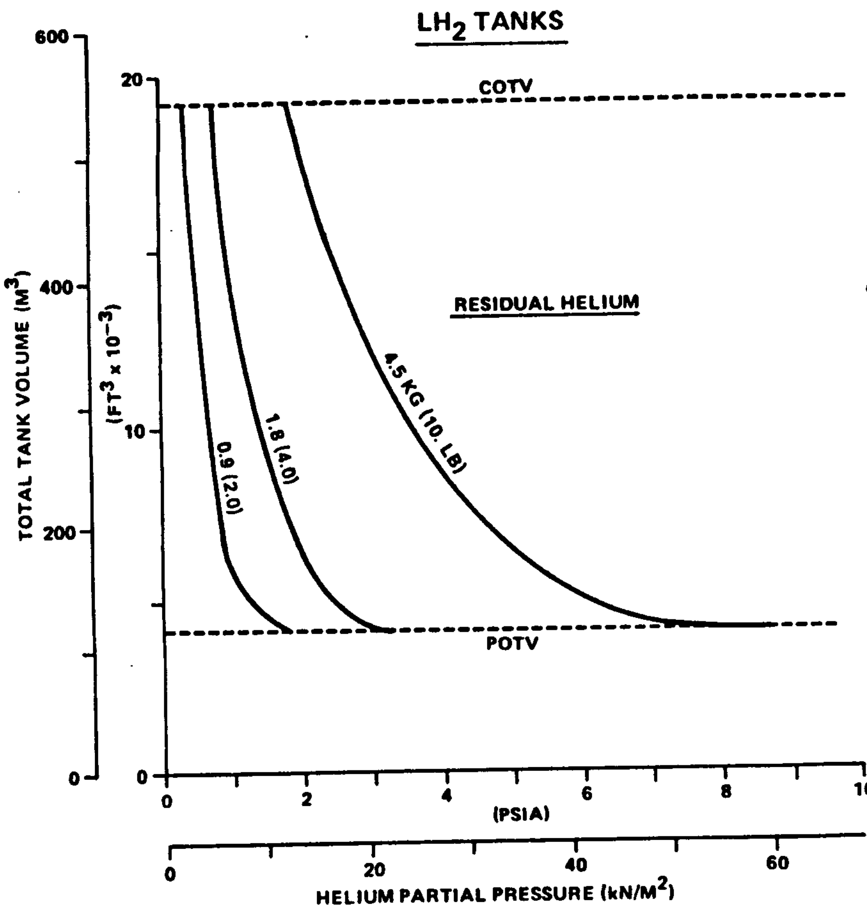


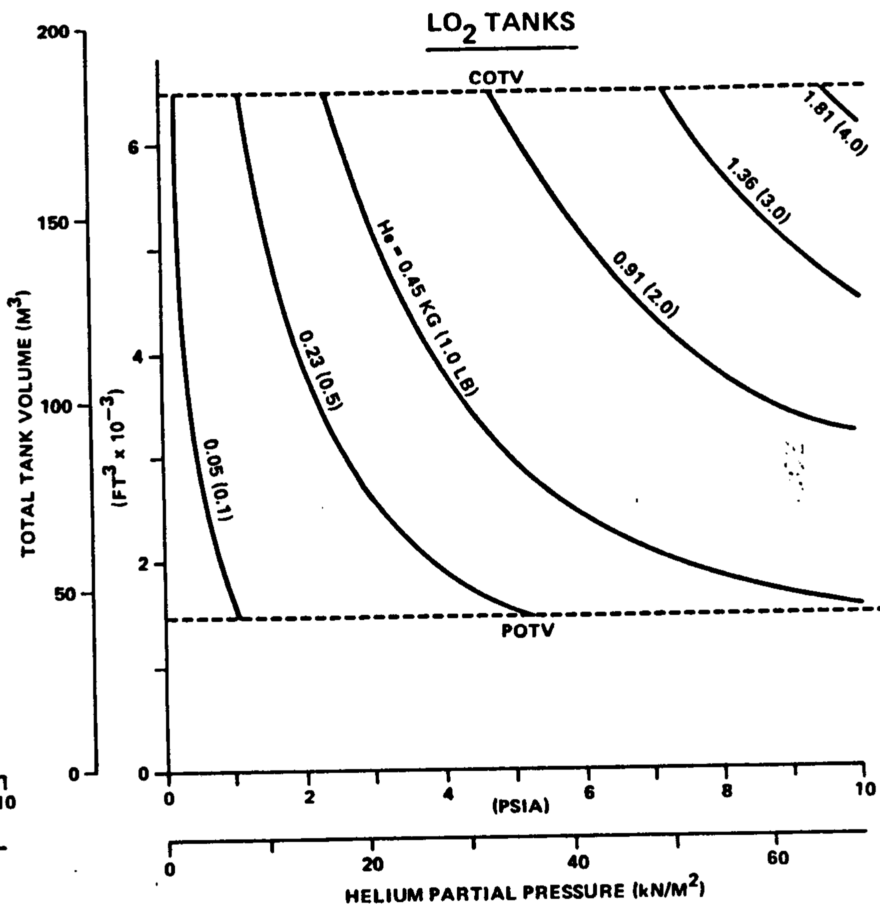
NOTE:

SUPPLY TANK VOLUME = $85 M^3$ ($3000 FT^3$)

EP6566

RESIDUAL HELIUM PARTIAL PRESSURES AT 97% FILL LEVEL

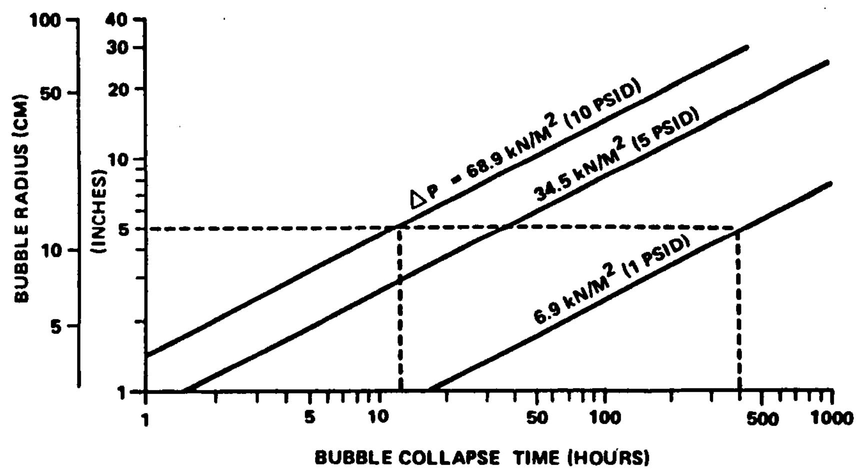




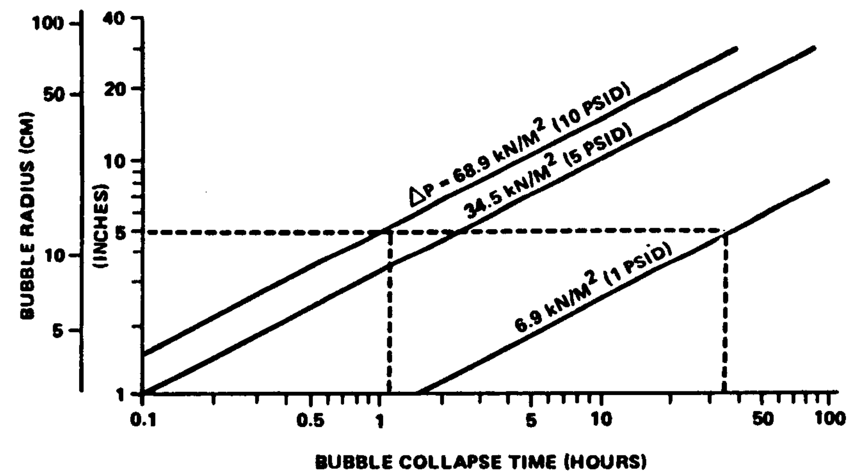
EP6565

PROPELLANT BUBBLE COLLAPSE BY INCREASING ULLAGE PRESSURE

LIQUID HYDROGEN



LIQUID OXYGEN



NOTE: ΔP = ULLAGE PRESSURE – SATURATION PRESSURE

CONCLUSION: COLLAPSE OF BUBBLES IN START BASKETS COULD REQUIRE ACTIVE CIRCULATION

EP6600

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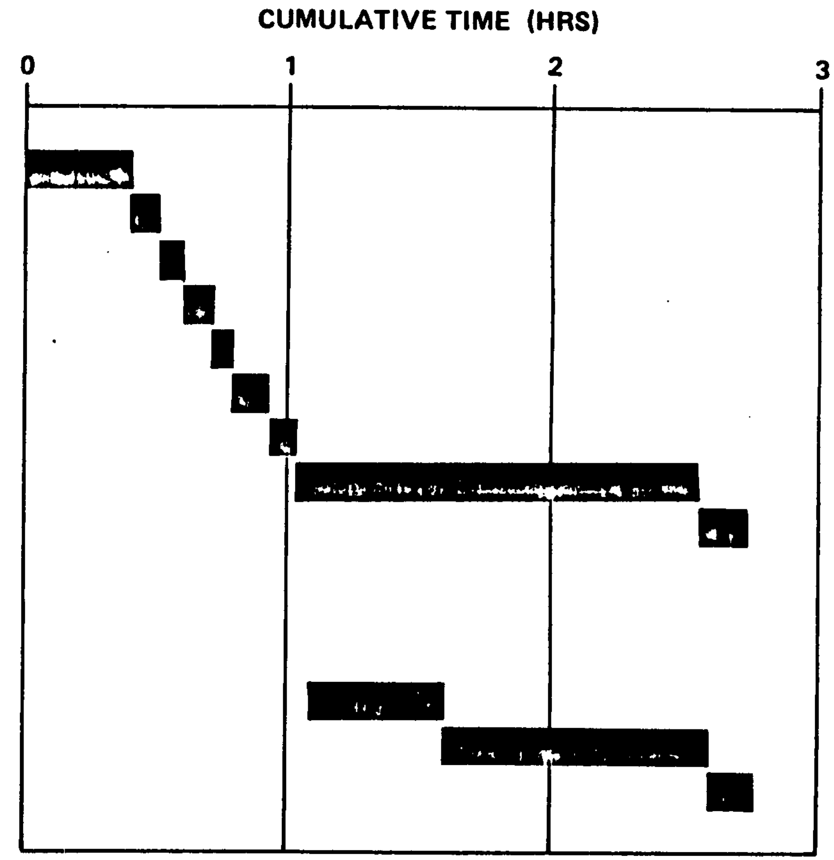
√ CONCLUSIONS

EP6567

POTV PROPELLANT TRANSFER TIMELINE

EVENT

- LH_2 TRANSFER
  - 1) INITIAL LH_2 TANK VENT
  - 2) PRECHILL
    - INJECT LH_2 AND HOLD
    - VENT TANK
    - INJECT LH_2 AND HOLD
    - VENT TANK
    - INJECT LH_2 AND HOLD
    - VENT TANK
  - 3) FILL
    - LH_2 TRANSFER
    - TOPPING FLOW RATE
- LO_2 TRANSFER
  - 1) INITIAL LO_2 TANK VENT*
  - 2) FILL
    - LO_2 TRANSFER
    - TOPPING FLOW RATE



NOTES:

- TWO OR MORE ADDITIONAL VENT CYCLES REQUIRED IF HELIUM PRESENT
- TIMELINE IS FOR REFUELING TO 50% LEVEL

EP6595

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CONCLUSIONS

PRE–CHILL PREPARATIONS

- DILUTION OF HELIUM RESIDUALS PRIOR TO REFUELING REQUIRED TO PREVENT:
  - EXCESSIVE PRESSURES AT END OF FILL
  - INACCURATE KNOWLEDGE OF PROPELLANT VAPOR PRESSURES
  - START BASKET HELIUM ENTRAPMENT
  - INACCURATE THERMODYNAMIC MASS GAUGING
- APPROXIMATE DILUTION LEVELS REQUIRED (POTV)
  - $LH_2 \leq$ .9 KG (2 LBS)
  - $LO_2 \leq$ .09 KG (.2 LBS)

  } FURTHER DILUTION REQUIRED IF THERMODYNAMIC MASS GAUGING UTILIZED
- PROCEDURAL/TECHNOLOGY CONCERNS
  - DURATION OF VENT/HOLD CYCLES
  - KNOWLEDGE OF HELIUM RESIDUAL MAGNITUDE

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EP6596

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CONCLUSIONS

TRANSFER LINE/TANK CHILLDOWN:

- REQUIREMENT: REDUCE TRANSFER LINE/TANK WALL TEMPERATURES SUFFICIENTLY TO PREVENT EXCESSIVE LINE PRESSURE/FLOW SURGES AND TO ENABLE A NON–VENTED TANK FILL
- PROCEDURAL/TECHNOLOGY CONCERNS:
  - TANK CHARGE/HOLD/VENT CYCLE DEFINITION
    - SEMI–EMPIRICAL MODELING LACKS EXPERIMENTAL DATA
    - LACK OF HARDWARE EXPERIENCE
    - WALL CHILLDOWN CRITERION: CURRENT RANGE = 95°K TO 200°K (170°R TO 360°R)
    - CHARGE MASS/FLOWRATE SELECTION: CURRENT LH_2 RANGE = 20 TO 70 KG (40 TO 155 LB) @ .5 TO 1.5 KG/SEC (1 TO 3 LB/SEC)
  - LACK OF TRANSFER LINE CHILLDOWN EXPERIENCE – PREVENTION OF EXCESSIVE SURGES AND LINE LOADS
  - INSTRUMENTATION TO MONITOR CHILLDOWN PROCESS

LP6597

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CONCLUSIONS

TANK FILL

- REQUIREMENT: LH_2 & LO_2 TANK FILL WITHOUT VENTING
- PROCEDURAL/TECHNOLOGY CONCERNS:
  - ASSURANCE OF ADEQUATE CIRCULATION TO MAINTAIN NEAR–THERMAL EQUILIBRIUM, i.e., LOW PRESSURES
    - GOOD MIXING/HEAT EXCHANGE BETWEEN ULLAGE/LIQUID REQUIRED
    - EXISTING SEMI–EMPIRICAL MODELS LACK EXPERIMENTAL DATA
    - LACK OF IN–FLIGHT HARDWARE EXPERIENCE
    - MECHANICAL MIXER PROBABLY REQUIRED
  - LACK OF ZERO–G MASS GAUGING DEVICE
  - SPECIAL FILL PROVISIONS FOR START BASKET
    - BLEED LINE FOR DIRECT FILL OF BASKET
    - ACTIVE CIRCULATION TO ASSURE ENTRAPPED VAPOR COLLAPSE
  - SUPPLY TANK VAPOR PRESSURE $\leqslant$ 2.2 kN/M^2 (15 PSIA), NO HELIUM PASSAGE ALLOWABLE
  - PREVENTION OF EXCESSIVE TRANSFER LINE LOADS AT $\dot{m}$ = 1–1.5 KG/SEC (2–3 LB/SEC)